Middle Devonian Stratigraphy and Conodont Biostratigraphy, North-Central Ohio[1]

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ABSTRACT. Devonian sedimentation in north-central Ohio began in warm, somewhat restricted seas in which the Bois Blanc and Amherstburg formations (latest Early to earliest Middle Devonian) accumulated. Increased restriction, reflected by the Lucas Dolomite facies, prevailed until middle *costatus*-Zone time when marine transgression initiated deposition of the Columbus Limestone. A wave-erosional episode left a disconformity atop the Columbus that truncates the lower *australis* Zone near Sandusky and progressively lower levels southward; the uppermost *costatus* Zone is thus missing in central Ohio. The Delaware Limestone represents a transgressive-regressive cycle, apparently during *kockelianus*-Zone time, which was followed by an extensive erosional period in which three endemic species of *Icriodus* died out. The Plum Brook Shale is in the upper *ensensis* Zone (lowest upper Middle Devonian) and reflects the If T-R cycle. The Prout Dolomite contains a Middle *varcus* Subzone fauna and represents the IIa T-R cycle (Taghanic onlap). Regional correlatives of the Prout currently assigned to the Lower *varcus* Subzone are probably of Middle-*varcus* age. Considerable disagreement exists between the fairly extensive Middle Devonian conodont-biostratigraphic data in the Lake Erie region and recent correlations based on volcanic ash beds and/or geophysical logs.

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INTRODUCTION

The Middle Devonian Series in north-central Ohio has been studied by several generations of paleontologists and stratigraphers, and many controversies have arisen in regard to age determinations and correlations with surrounding regions. Early workers concentrated on macrofaunas and attempted to correlate all units with the New York Standard. The work of Cooper et al. (1942) reflects the culmination of these efforts.

Early conodont studies in this region were restricted to Givetian (upper Middle Devonian) shales (Stauffer 1938) and an Eifelian (lower Middle Devonian) bone bed (Stewart and Sweet 1956). Extraction of conodonts from the Middle Devonian carbonates of surrounding regions did not begin until the late 1960s, and my work began in the late 1970s, by which time the level of uncertainty and disagreement regarding interregional correlation was perhaps as high as it had ever been.

Conodontologists tend to view the objects of their studies as "superbugs" that are more capable of resolving biostratigraphic uncertainty than are other taxa (e.g., Johnson et al. 1985, p. 567). A major purpose of this paper will be to point out the degree to which conodonts from the Middle Devonian of north-central Ohio live up to that reputation. Other purposes are to summarize important studies of this region, both old and recent, and to present some new information from preliminary studies of Givetian strata.

Figure 1 shows the generalized stratigraphic column and geologic map of the Lower and Middle Devonian formations of north-central Ohio. All of these units will be discussed in following sections, although conodonts have been extracted only from the basal Columbus through the Prout. The conodont zonation of these units (plus that of the Bois Blanc Formation, which does not crop out in the region) is shown in Figure 2.

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TECTONIC SETTING AND PRE-EIFELIAN SEDIMENTATION

As seen in Figure 3, the Sandusky area lies on the southeastern flank of the Findlay Arch and northeastern margin and the Wabash Platform of Droste et al. (1975). Largely because of the tectonic and paleogeographic setting in which they lived, Middle Devonian conodonts of this region serve a number of purposes. Although restricted environments excluded diagnostic conodonts here during earliest Devonian sedimentation, the position on the edge of the marginal Appalachian Basin allowed the immigration of diverse and biostratigraphically significant faunas as normal-marine conditions became established. In addition, the cratonic setting apparently provided periodic quiet conditions in which fossils were preserved without being sorted or subjected to post-mortem transport. This has facilitated reconstruction of apparatuses and paleoecologic interpretations (Sparling 1981a, 1984).

Earliest Devonian sedimentation in north-central Ohio involved the cherty carbonates of the Emsian (late Early Devonian) Bois Blanc Formation, which extends from the Michigan Basin through the Chatham Sag into the Appalachian Basin and is thickest in subsident basin centers. It pinches out in the subsurface of eastern Erie County (Dow 1962) near the margin of the Wabash Platform, which probably remained largely above sea level during the Bois Blanc transgression. The conodont fauna of this unit in Ontario includes *Icriodus latericrescens robustus* (Uyeno et al. 1982); in New York it contains that subspecies and *I. huddlei* (Klapper and Ziegler 1967).

The Bois Blanc is overlain in eastern Erie County by the southeastern margin of the Amherstburg Dolomite, which extends from here to the eastern Lake Erie region, across the Algonquin Arch and throughout most of the Michigan Basin. The lower Amherstburg is considered to be of latest Emsian age; the upper is earliest Eifelian. Uyeno (Uyeno et al. 1982, Table 3) reported *I. latericrescens robustus* plus species of *Belodella* and *Dvorakia* from typical Amherstburg in Ontario.

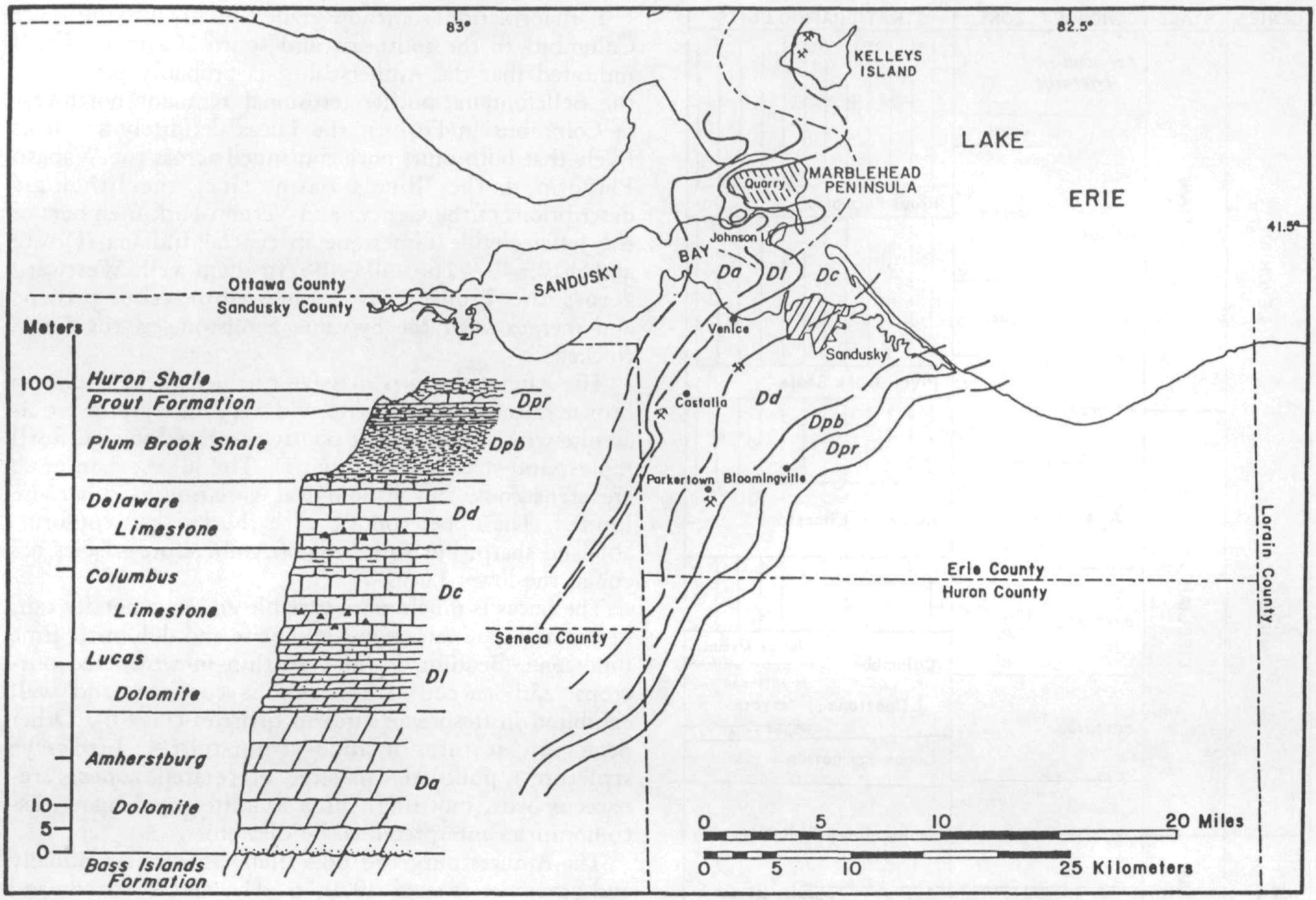

FIGURE 1. Generalized geologic map and stratigraphic column of the Lower and Middle Devonian formations in the Sandusky area. Quarries and some other localities referred to in the text are also indicated.

By early Eifelian time distinct sedimentary realms appear to have been established in different regions. The area of Amherstburg sedimentation described above was characterized by an endemic fauna (coral-mixed brachiopod subzone of Fagerstrom (1971)) and was likely shallow and warm. To the southeast (presumably south-poleward and subtropical at the time — e.g., Klapper and Johnson (1980), Text-Fig. 5) was a broad shelf on which carbonates (lower Columbus and Onondaga limestones) accumulated in cooler waters and a more diverse marine fauna was becoming established. Beyond that lay a deeper realm in which the Onondaga Limestone and equivalents were accumulating very slowly in a starved-basin setting (Mesolella 1978, Koch 1981).

EIFELIAN STRATIGRAPHY AND SEDIMENTATION

Figure 4 is a generalized isopach map of organic carbonates, evaporites, and mature sandstones of late Emsian and Eifelian age (exclusive of thin units in black shales) that overlie and overlap the Bois Blanc. The purpose is to show that the Sandusky and central Lake Erie region lies between two sedimentary basins whose histories during this time were strikingly different. The isopachs for the Appalachian Basin are from Mesolella (1978) and show the relatively thin carbonates of marine origin that accumulated through early Eifelian time in the deep basin areas, after which mud from Acadian orogenic lands became the dominant sediment. By contrast, the Michigan Basin subsided yet filled with chemical and biochemical precipitates of salts provided by extensive influx, including that from the Appalachian Basin (Gardner 1974).

The Eifelian carbonates of north-central Ohio record the changing conditions on the outer margin of a major entryway into the Michigan Basin; conodonts provide a reasonably accurate time frame for these events. The Amherstburg and Lucas, which together form the Detroit River Group in this region, represent an early transgressive-regressive phase characterized by restricted conditions. The Columbus represents a normal-marine transgression that probably reached well into the Michigan Basin by the end of *costatus*-Zone time (Sparling 1981b, 1985). The argillaceous Delaware resulted from a transgressive-regressive cycle during late Eifelian time, when fine carbonate and terrigenous mud commingled on the western shelf of the Appalachian Basin.

DETROIT RIVER GROUP. The Detroit River strata of the region were originally placed in the "Corniferous" by Newberry (1870) and were later classified as "Lower Helderberg" by Orton (1888). Prosser (1903) named equivalent rocks on the western side of the Findlay Arch the Lucas Limestone (=upper "Monroe Group"), which was later incorporated into the Detroit River "Series" (Lane et al. 1909) as the unit above the Amherstburg "bed". The Amherstburg and Lucas were eventually recognized by Carman (1927) along the north shore of the Marblehead

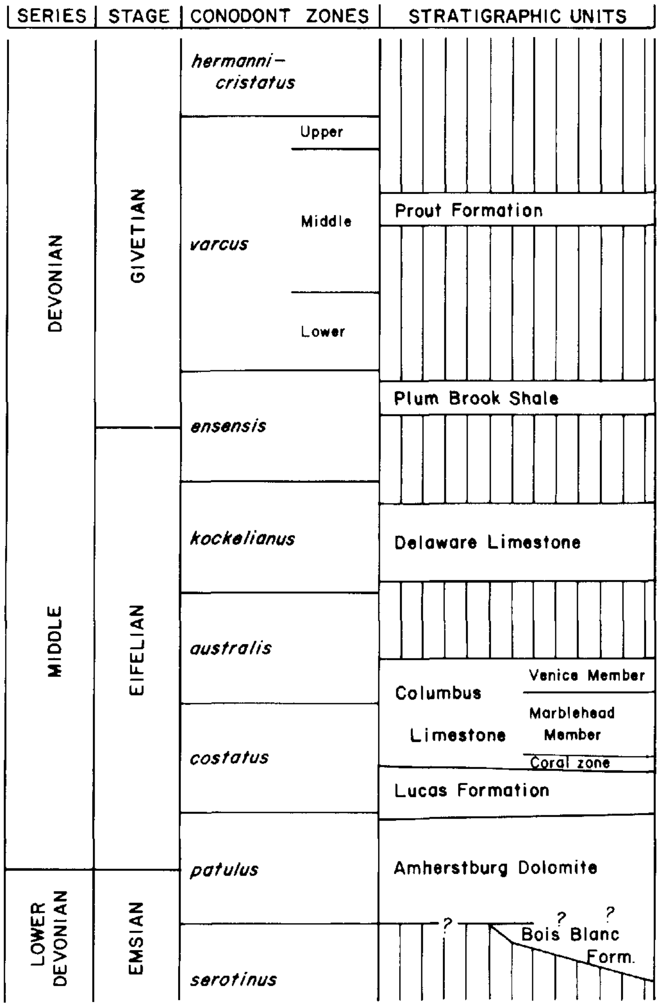

FIGURE 2. Conodont zonation of the Lower and Middle Devonian of north-central Ohio. Conodonts have been extracted from nearly all levels above the Lucas.

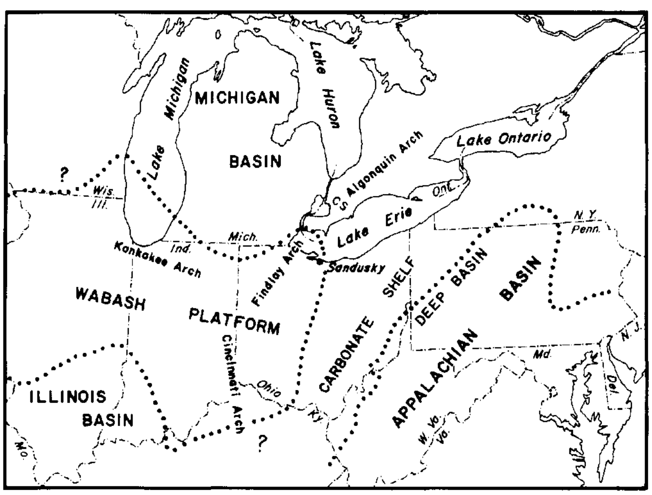

FIGURE 3. Tectonic setting during Eifelian time. Major sources are Droste et al. (1975) and Mesolella (1978). CS = Chatham Sag.

Peninsula. The lower Amherstburg does not crop out, but a core through the entire Detroit River on the Marblehead Peninsula was determined by Kerr (1950) to include 30.2 m of Amherstburg and 15.5 m of Lucas.

Both formations somehow grade laterally into the lower Columbus to the southeast and south. Carman (1927) indicated that the Amherstburg is probably present in the Bellefontaine outlier (erosional remnant northwest of Columbus in Fig. 4), the Lucas definitely so. It is likely that both units once continued across the Wabash Platform to the Illinois Basin, since the lithologic descriptions of the Geneva and Vernon Fork members of the Jeffersonville Limestone in central Indiana (Droste and Shaver 1975, pp. 403-406) fit them well. Westward across the Findlay Arch the Amherstburg thins and merges with the Sylvania Sandstone as the Lucas thickens.

The Amherstburg is massive to thick-bedded, tan to brown calcareous dololutite and very fine-grained dolarenite with abundant but poorly preserved fossils, fossil molds, and sparite casts (Fig. 5). The lowest 3 m or so are arenaceous, but lithological variation is otherwise limited. The upper contact with the Lucas is conformable and sharp, but thin beds of Amherstburg facies occur in the lower Lucas.

The Lucas is much more variable and is generally tan, brown and gray calcareous dololutite and dolomitic lime mudstone. Bedding is thick to thin in weathered outcrops; carbonaceous lamination is common and well exhibited in fresh exposures in quarries (Fig. 6). Other petrologic features include stromatolites, bird's-eye structures, poikilitic sparite, brecciated zones, arenaceous beds, mottling, microstylolites, and many disconformities interpreted to be diastemic.

The Amherstburg and Bois Blanc are similar faunally and otherwise (Briggs 1959, p. 41), and Bjerstedt and Feldmann (1985, p. 1042) consider the Amherstburg to be a platform facies of the Bois Blanc in north-central Ohio. Both units probably accumulated in warm, shallow seas, which were restricted to the basins and the Chatham Sag during Bois Blanc sedimentation. With late Emsian transgression, this environment retreated from all of the Appalachian Basin except its present northwestern margin but also expanded onto the margins of the Wabash Platform.

At some early Eifelian time, increased restriction and salinity within the region of Amherstburg sedimentation caused a decrease in faunal diversity and abundance and the onset of conditions reflected by the Lucas Formation. The intercalated lithologies on the Marblehead Peninsula suggest intermittent reversals, but eventually the Lucas environments expanded. The resultant displacement of less saline environments was essentially regressive. Slow marine-transgressive displacement then reduced the areal extent of Lucas environments, but they persisted in some regions (e.g., southern and western Michigan Basin) until late Eifelian time.

Figure 7 shows the assumed maximum extent of the Lucas and equivalent units in the Illinois and Appalachian basins (zero isopach) and the thickness into the Michigan Basin. The intention is to show the paleogeography at about the time of the regressive expansion. Existence of a continuous "Lucas Sea" at that (or at least a later) time is supported by the finding of a Detroit River fauna in the upper Grand Tower of Illinois (Linsley and Kesling 1982). Actually the term sea is perhaps best applied to the region of greatest accumulation, where penesaline and saline facies accumulated, and to the vi-

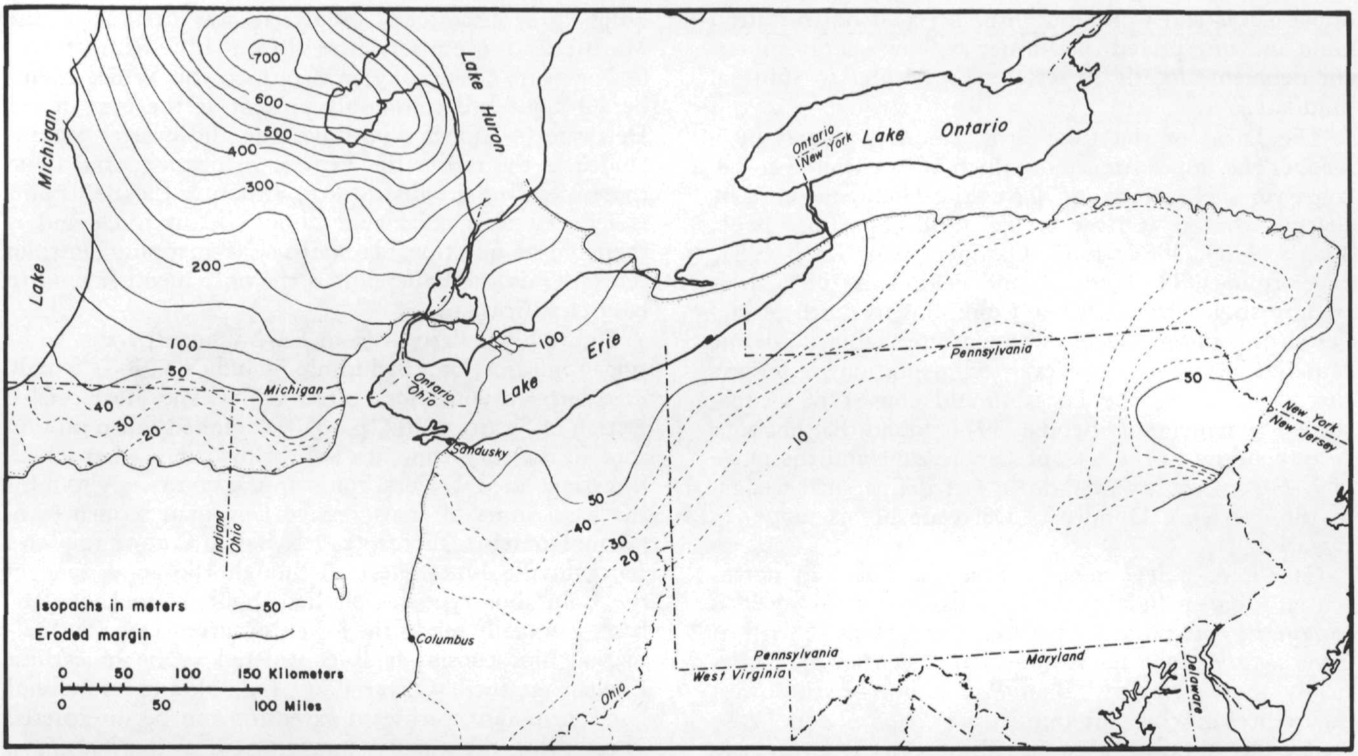

FIGURE 4. Generalized isopach map of late Emsian and Eifelian sediments exclusive of shale sequences. Data are from Sanford (1968), Doheny et al. (1975), and Mesolella (1978).

FIGURE 5. Uppermost Amherstburg on the north shore of the Marblehead Peninsula.

FIGURE 6. Upper Lucas in the Marblehead quarry.

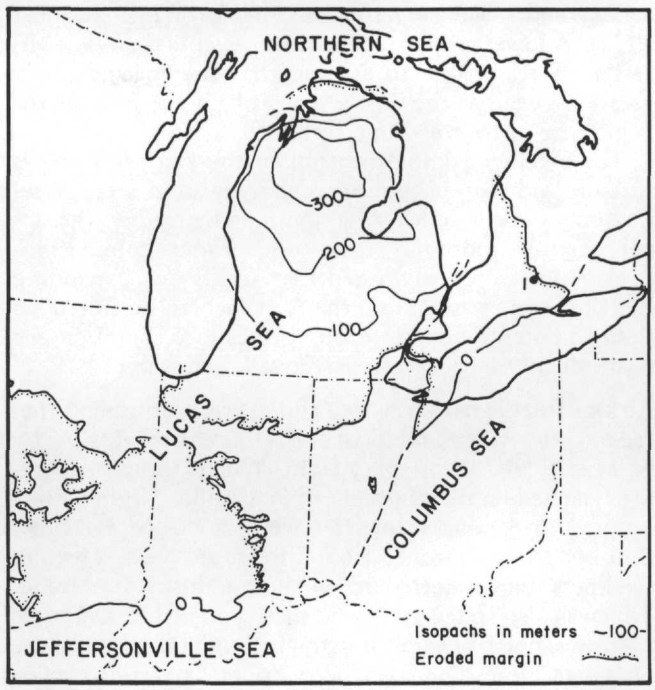

FIGURE 7. Extent and generalized isopachs of the Lucas and equivalents.

cinity of major marine inlets as described by Briggs (1959), Gardner (1974), and Fagerstrom (1983). In more positive tectonic settings, however, the Lucas environment consisted largely of carbonate flats that were exposed intermittently (Droste and Shaver 1975, Sparling 1984, Bjerstedt and Feldmann 1985), so perhaps "Lucas Sea and Mudflats" would be a more appropriate term. Bjerstedt and Feldmann (1985) studied in detail the upper Lucas and Columbus lithofacies in north-central Ohio and interpreted the former as "low energy, nutrient deficient, locally hypersaline, peritidal to subtidal mudflats."

The Lucas of the Lake Erie region is essentially a wedge, the upper surface of which is interpreted to become younger toward and across the Michigan Basin by several workers (Oliver et al. 1968, Sparling 1971, 1981b, 1983, 1984, 1985, Gardner 1974, Koch 1981, Fagerstrom 1982, Bjerstedt and Feldmann 1985). It is conformably overlain by the Columbus in north-central Ohio; disconformities elsewhere are probably diastemic consequences of near-sea-level sedimentation. It follows that strata above the Lucas should consist of wedge-shaped increments. Diffendal (1971) found that horizons corresponding to the tops of a spore zone and the range of *I. latericrescens robustus* do in fact define such wedges in the overlying Dundee (=Delaware of his usage) in Ontario.

Conodonts a few meters above the Lucas in nortn-central Ohio include specimens classified as *Polygnathus linguiformis bultyncki?* (Sparling 1983, Figs. 5, 6). A lower *costatus*-Zone age is indicated since they are phyletically more primitive than *P. l. linguiformis*, lowest occurrences of which are in the upper *costatus* Zone. Also a unit (=Columbus of some) above typical Lucas near Ingersoll, Ontario (loc. I on Fig. 7) contains a form intermediate between *P. costatus patulus* and *P. c. cooperi* (Uyeno et al. 1982, Table 4b) that is restricted to the *patulus* and lower *costatus* zones in New York (Klapper 1971). A lower-*costatus* age is thus possible there as well, and it is reasonable to assume that the marine transgression began at the zero isopach of Figure 7 about the beginning of *costatus*-Zone time.

The extent of dolomitization in the Detroit River is variable and may have resulted largely from seepage refluxion. In the Findlay-Algonquin arches region the upper part is commonly limestone. Fagerstrom (1983, p. 315) in essence suggested that steady and expanding flux of marine waters from the Appalachian Basin tended to flush potential dolomitizing brines into the Michigan Basin during late Detroit River sedimentation.

COLUMBUS LIMESTONE. The name Columbus limestone was first used in north-central Ohio by Newberry (1873) for "very light colored limestone" being quarried on the Marblehead Peninsula. Higher strata exposed in Sandusky quarries were described as "blue, thin-bedded limestone, from fifteen to twenty feet in thickness" and referred to as the Sandusky limestone. This was also stated to be the rock quarried at Delaware (24 miles north of Columbus), which later came to be the Delaware Limestone. Newberry apparently later viewed his Sandusky as equivalent to the Columbus of central Ohio, as did C. K. Swartz (Prosser 1905, pp. 440-441). Prosser (1905, pp. 434-436) and Swartz (1907) established the actual top of the Columbus in the Sandusky region; Swartz provided the present classification.

Figure 8A is taken directly from Swartz' (1907) illustration of members and spiriferid zones of the Columbus that he traced from north-central Ohio to the type region of central Ohio. The lowest member was named the Bellepoint, described as 7.3 m of brown limestone "with coral bed near top and conglomerate at base." The overlying "gray limestone" of Swartz was designated the Marblehead Member; his "lower blue limestone" (=Newberry's Sandusky) was termed the Venice Member. A bone bed commonly present at the base of the Delaware (="upper blue limestone" of Swartz) was included at the top of the Venice. In north-central Ohio these members are distinctive, although the Bellepoint is reduced to a coral zone about 1-2 m thick and is therefore of questionable status as a mapping unit; in central Ohio the Bellepoint is the only member used in later classifications.

Figure 8B is derived from 8A but incorporates additional information, including Stauffer's (1909) widely used lettered zones for central Ohio. The Marble Cliff section of Swartz (1907, p. 650) extended down only to zone E; the coral zone lies well below the level at which he extrapolated it. Coral zones appear commonly to form the basal units of transgressive Devonian sequences of normal-marine facies (e.g., basal Onondaga and Jeffersonville limestones). Although the coral zone of the Columbus type region lies about 11 m above the base, it actually marks the lowest occurrence of a normal-marine biocoenosis. It is considered to be of earliest Eifelian age there (Oliver 1976, Fig. 3), and its more or less continuous northward extension can be interpreted as recording the gradual transgression of the margin of the Columbus Sea (the section in Fig. 8B is actually about 45° from the depositional strike). If so, the overlying strata should represent diachronous lithosomes, and the northward diminishing thickness between the coral zone and the *Brevispirifer gregarius* Zone is to be expected if this biostratigraphic zone has any time-stratigraphic significance.

In addition, the top of the Columbus is a disconformity, and the northward increase in thickness of strata above the *B. gregarius* Zone (and above the *"Spirifer" acuminatus* Zone of Fig. 8A as well) suggests that the top of the Columbus becomes younger northward. A diminishing hiatus northward could also be surmised from evidence that the Sandusky area is tectonically more negative and from the fact that no corresponding disconformity at all has been reported farther north in Ontario. Further evidence was supplied by Bownocker (1898, p. 39). In regard to the relationship between faunas above and below the top of the Columbus, he stated:

> "It appears therefore, that the difference between the faunas above and below the bone-bed in the central Ohio area is not great, that this difference is most conspicuous at Delaware and diminishes to the north, being least at Sandusky."

However, Bownocker drew no conclusion from this evidence, nor did Prosser (1905), who quoted this same passage without comment regarding the implications.

In practice, the top of the Columbus was considered until recently to be synchronous, a view that was supported by existence of *"Spirifer" duodenarius* near the top both to the north and south (Swartz 1907, Wells 1947). In addition, the hiatus was considered negligible, to the extent that virtually all current correlation charts show a conformable relationship for the Columbus and Delaware.

One of the major contributions made by conodonts in this region involves the evidence they provide in regard

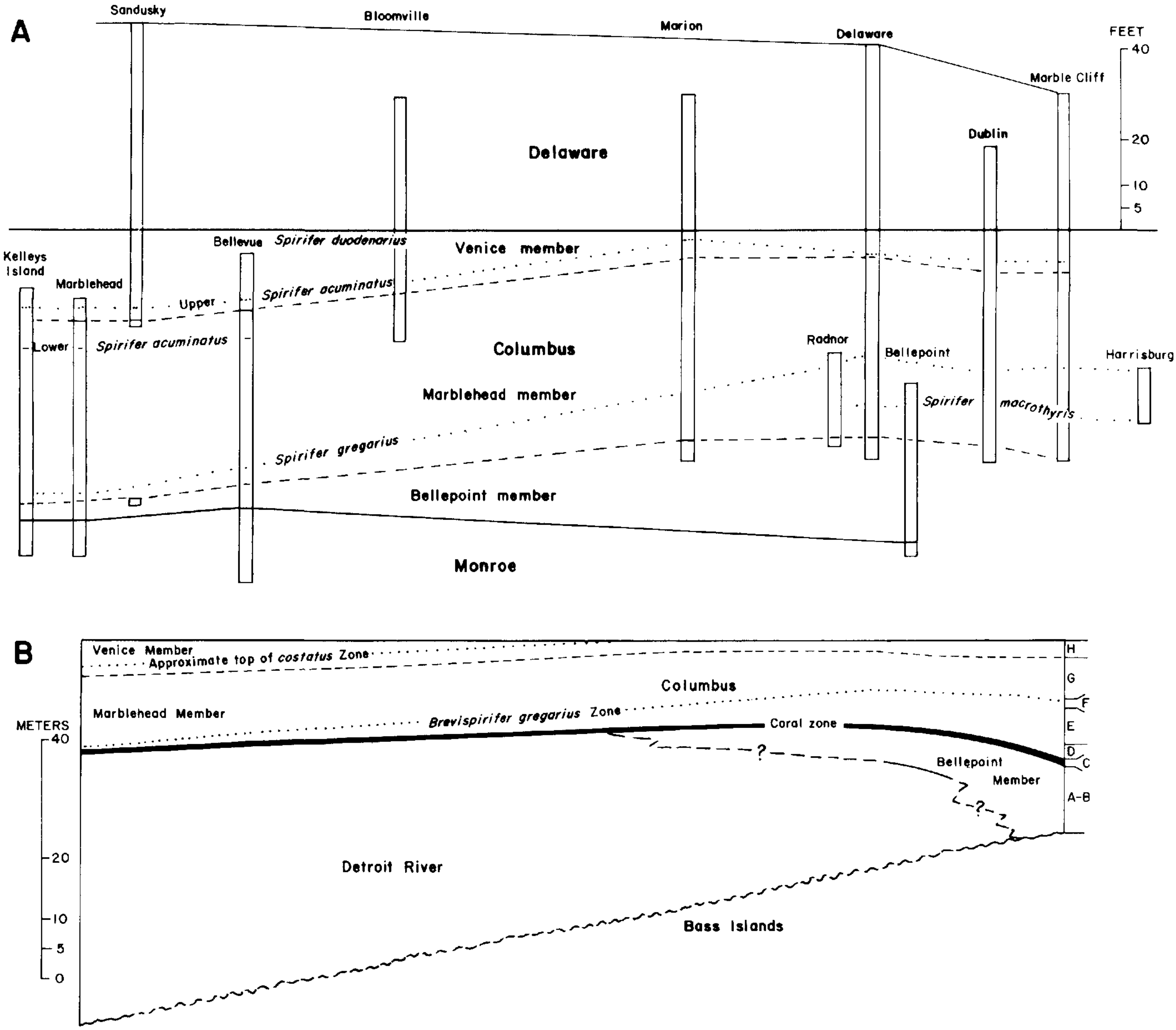

FIGURE 8. Stratigraphic section from north-central Ohio to the Columbus type region from Swartz (1907, 8A), with additional information added (8B) from Stauffer (1909) and Sparling (1983).

to these matters. Ramsey (1969) reported *I. latericrescens robustus* and *P. c. costatus* from the uppermost Columbus in central Ohio. In north-central Ohio the former ranges only into the lower Venice; the latter is associated above that level with species diagnostic of the *australis* Zone (Sparling 1983). The approximate top of the *costatus* Zone in Figure 8B is assumed to correspond to the highest occurrence of *I. latericrescens robustus* (see Sparling 1983, p. 836, 1985, Fig. 3). The gradual northward increase in the interval between the *B. gregarius* Zone and the *costatus*-Zone top is consistent with the model discussed above.

Figure 9 shows the sections of the Columbus and Delaware studied by the author (see also Sparling 1983, 1984). A more extensive and detailed study of Columbus lithofacies was made by Bjerstedt and Feldmann (1985), who included quarries at Castalia, Johnson Island, Marblehead Peninsula, Kelleys Island, and Pelee Island, Ontario (about 20 km north of Kelleys Island). Their overall interpretation is very similar to that shown in Figure 9.

Representative conodont species from the Marblehead and Venice members are shown in Figures 10 and 11. Sparling (1983, 1984) can be consulted for complete details of conodont distribution.

Figure 12 shows the basal coral zone on the Marblehead Peninsula. Bjerstedt and Feldmann (1985) described this unit as wackestone-packstone facies with a "rich and diverse fauna" and interpreted it as representing "a medium-energy subtidal bank with a crest only seldom above wave base." They considered the lower Marblehead to involve "a low energy, semi-restricted, subtidal lagoon biotope" with localized mud knoll biotopes representing slightly higher energy levels.

At the Parkertown quarry the basal coral zone is absent, and the Lucas/Columbus contact is less distinct (Fig. 13). Janssens (1970) considered the lower Marblehead here to consist of Detroit River facies (i.e.,

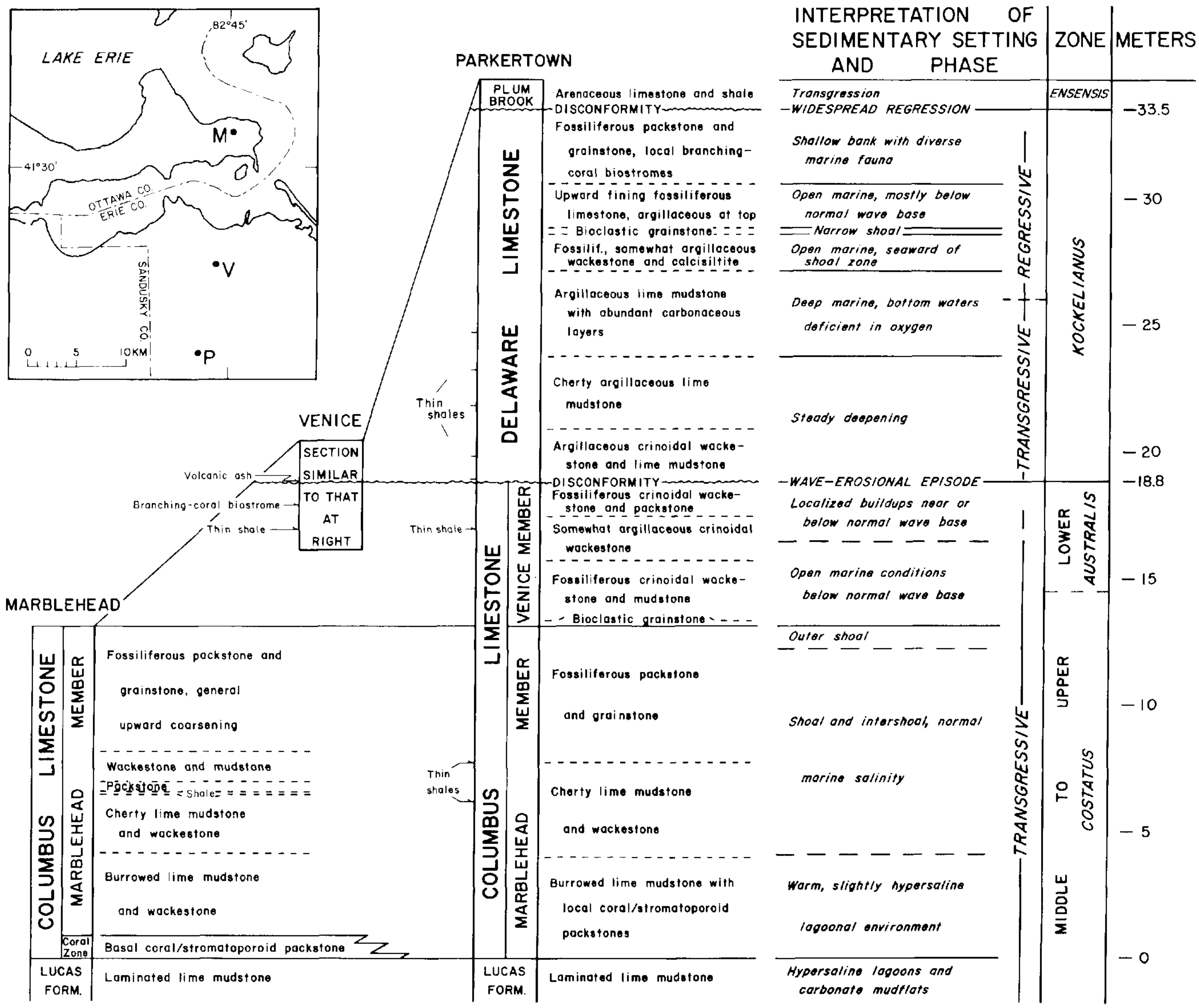

FIGURE 9. Summary descriptions of the Columbus and Delaware of north-central Ohio with interpretation of sedimentary conditions. Figure originally appeared in GSA Special Paper 196, p. 114 (Sparling 1984).

Lucas lithology); Oliver (1976) reached a similar conclusion. Fagerstrom (1982, p. 59) placed the base of the Columbus about 3.8 m higher than indicated in Figure 13. However, conodonts in the lower Columbus at Parkertown, as defined herein, are similar in diversity and abundance to those in the same interval on the Marblehead Peninsula (Sparling 1983, Figs. 5, 6), whereas they are virtually nonexistent in normal Lucas facies (Uyeno et al. 1982, Tables 4a, b).

The upper Marblehead is largely fossiliferous grainstone. Bjerstedt and Feldmann (1985, p. 1040) characterized it as "a very well aerated, medium- to high-energy, nutrient-rich, subtidal shoal biotope." This facies was traced continuously to central Ohio by Chapel (1975) and northward by Bjerstedt and Feldmann as far as Pelee Island, where it makes up most of the exposed section.

The top of the Marblehead is generally an abraded surface, in part rippled to mega-rippled (for discussion see Bjerstedt and Feldmann 1985, p. 1040), although at the Parkertown quarry the contact is stylolitic. Abraded surfaces occur at the base of Stauffer's H zone in central Ohio (Fig. 8B) as well and could represent a diachronous feature caused by wave action on the outer margin of the shoal represented by the upper Marblehead facies.

The entire Marblehead Member is tan to light brown and weathers tan, whereas the Venice is gray to grayish tan and weathers gray. At Parkertown, the Venice includes a basal grainstone, but the characteristic facies consists of argillaceous, pyritic mudstone and wackestone with a diverse fauna. It is interpreted to reflect quiet conditions below normal wave base. Conodont diversity in the lower to middle Venice fortunately allows rather precise correlation. Pyrite, argillaceous admixtures, and conodont diversity all diminish in the uppermost meter or so.

DELAWARE LIMESTONE. Formal naming of the Delaware Limestone is generally attributed to Orton (1878, p. 606), and the name was first used in north-central Ohio by Prosser (1905). It is typically thin bedded and resembles the Venice but is more argillaceous, and the fresh rock is brownish in hue.

Prosser's (1905) and Stewart's (1955) reviews of the early work on Delaware classification and correlation

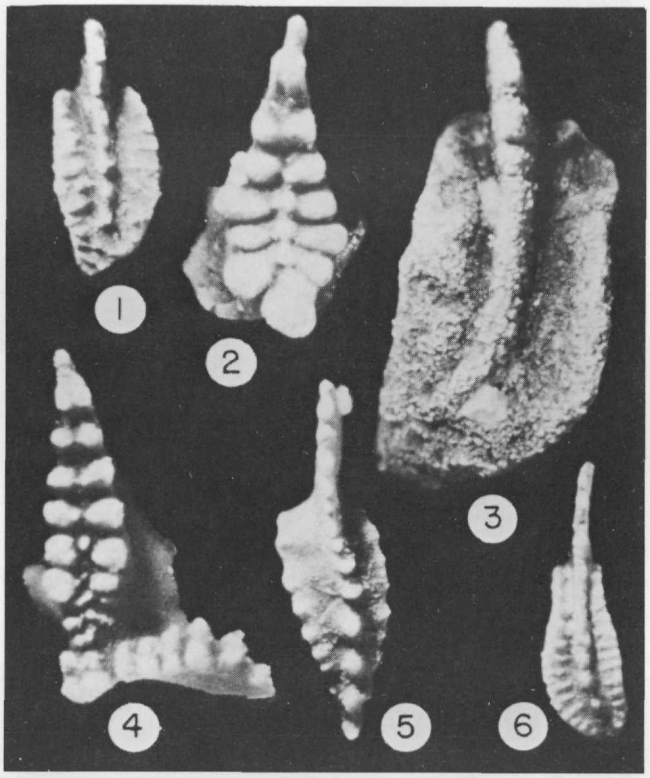

FIGURE 10. Conodonts from the Marblehead Member at the Marblehead and Parkertown quarries (previously illustrated in Sparling 1983—see for exact stratigraphic position). All are upper views, ×40. 1, *Polygnathus cooperi cooperi* Klapper, S76M5a; 2, *Icriodus orri* Klapper & Barrick, S77Pla; 3, *P. linguiformis bultyncki* Weddige ?, S76M6a; 4, *I. latericrescens robustus* Orr, S76M13a; 5, *P.* aff *P. trigonicus* Bischoff & Ziegler of Klapper (early form), S77P12b; 6, *P. costatus costatus* Klapper, S77P11a.

FIGURE 12. Lucas/Columbus contact in the Marblehead quarry. Hammer pick is on the highest of many diastems in the Lucas. Contact (base of coral zone) is 38 cm above this horizon.

show that once the Delaware was clearly differentiated from the Columbus, all biostratigraphic information pointed to a Hamilton age for the former. Correlation with the lower Hamilton Marcellus Shale of New York was therefore well established when Oliver (1967) correlated a volcanic ash bed just above the base of the Delaware near Sandusky (at the quarry south of Venice—Figs. 1, 14) with one at the base of the Seneca Limestone Member of the Onondaga in New York. In Oliver's view, the Seneca of western New York is a facies of the lower-Marcellus Union Springs Shale Member and

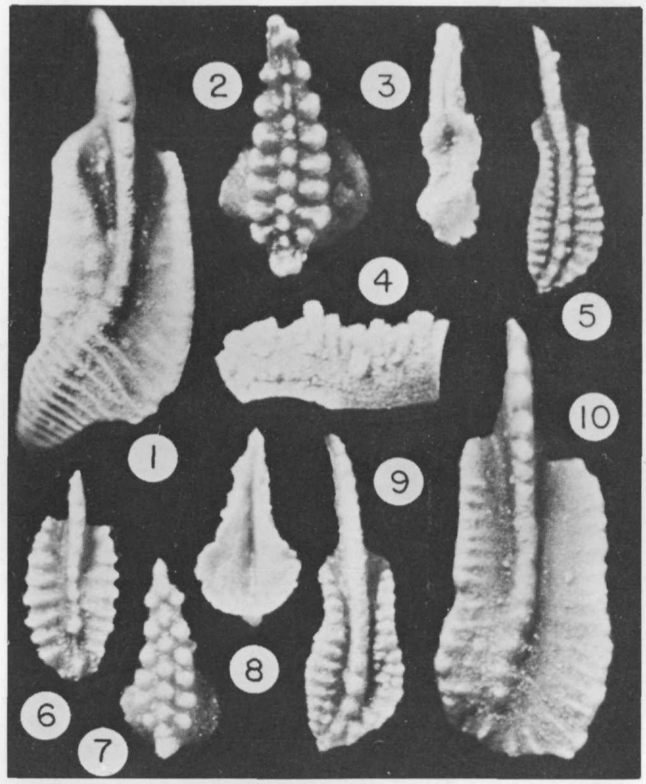

FIGURE 11. Conodonts from the Venice Member at the Venice quarry (about 2 km south of Venice) and the Parkertown quarry, numbered in stratigraphic order (all previously illustrated in Sparling 1983—see for exact positions). Upper views except as indicated. Specimen 1 is ×30, all others ×40. 1, *Polygnathus linguiformis linguiformis* Hinde (gerontic), S77P17e; 2, *Icriodus stephensoni* Sparling, S77P21h; 3, 4, lower and lateral views of *Tortodus kockelianus australis* (Jackson), S77V1a; 5, *P. costatus costatus* Klapper, S77P24s; 6, *P.* aff. *P. trigonicus* Bischoff & Ziegler of Klapper (late form), S77P24e; 7, 8 (lower view), holotype of *I. stephensoni* Sparling, S77P24v; 9, *P. pseudofoliatus* Wittekindt, S77P24x; 10, holotype of *P. linguiformis alingulatus* Sparling, S77P26c.

FIGURE 13. Lucas/Columbus contact at the Parkertown quarry (marked by hammer pick 0.67 m above distinctive pure, gray dolomite bed).

the overlying Cherry Valley Limestone Member of eastern New York (e.g., Oliver 1976, Fig. 3). However, Klapper and Ziegler (1979, Fig. 4) assigned the entire Seneca to the upper *costatus* Zone, whereas the Cherry Valley is in the *kockelianus* Zone (see also Klapper 1971).

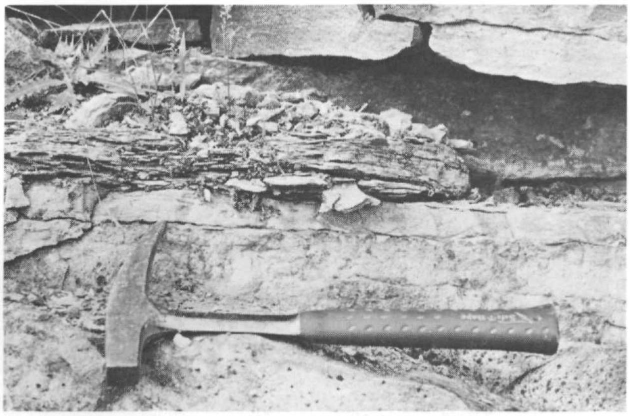

FIGURE 14. Venice/Delaware contact at the Venice quarry. Hammer pick marks the contact. The volcanic ash bed (Tioga of Oliver 1967) lies just above a thin basal conglomerate.

Nevertheless, correlation of the Delaware with the Seneca based on the "Tioga bentonite" became widely accepted. Rickard (1984) even used this horizon as a datum for Lower and Middle Devonian cross sections in the Lake Erie region and dismissed the biostratigraphic data to the contrary as being based on "well-known 'facies fossils' of little value for precise correlation."

Conodont evidence supporting correlation of the Delaware with the Cherry Valley rather than the Seneca was supplied by Ramsey's (1969) reporting of *Polygnathus eiflius* from the lower Delaware of central Ohio; this species is unknown elsewhere below the *kockelianus* Zone.

The first direct confrontation between conodonts and the volcanic-ash correlation involved the quarry south of Venice (Sparling 1979, 1983), where the ash bed is underlain (in descending order) by a basal conglomerate, a disconformity representing a considerable hiatus, upper Venice strata containing lower-*australis*-Zone conodonts, and older Columbus that *does* correlate with the Seneca (Figs. 9, 14). The refuting of the ash-bed correlation is another major contribution by conodonts and confirms earlier biostratigraphic correlations.

The Delaware seems everywhere to lie on an abraded smooth to undaform surface (Bates 1971) that was produced by wave erosion. The lowest 20 cm or so of Delaware at the Venice quarry (i.e., the one south of Venice) and at the Parkertown quarry resembles the uppermost Venice and contains the same conodont association (Sparling 1984, Figs. 4, 6). It thus appears that the erosional interval was followed almost immediately by sedimentation below wave base. As indicated in Figure 9, the Delaware above the lowest level is interpreted to record a deepening phase followed by regression. The distribution of conodonts appears to reflect these changing sedimentary conditions (Sparling 1984).

Representative conodont species from the Delaware are shown in Figure 15. The details of conodont distribution at the Venice and Parkertown quarries are given in Sparling (1983, 1984).

VOLCANIC ASH BEDS AND CORRELATION BY GEOPHYSICAL LOGS. Conodonts of the Lake Erie region have become involved recently in a controversy regarding

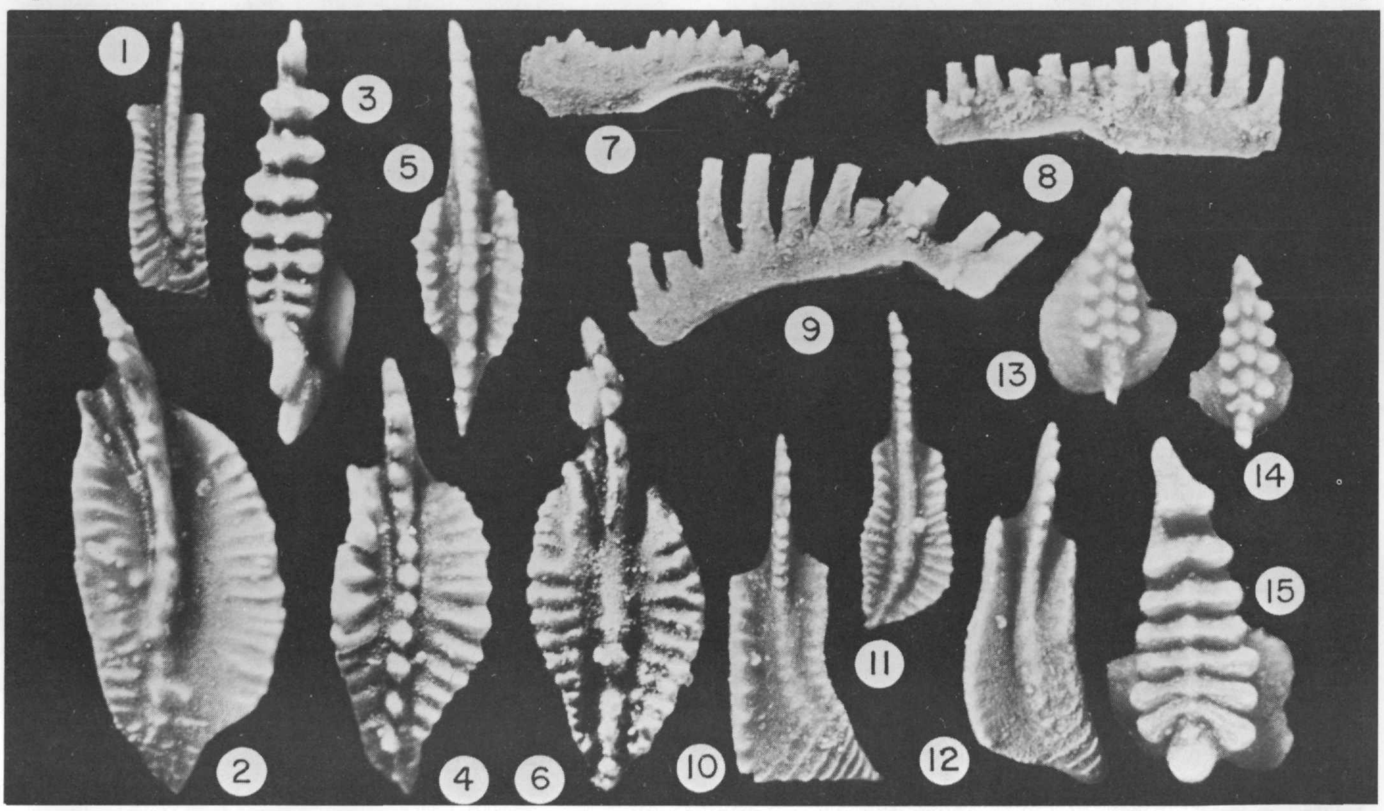

FIGURE 15. Conodonts from the Delaware at the Venice and Parkertown quarries, 1-9 from the lower Delaware, 10-15 from the upper — see Sparling (1983) for exact positions. All except 1, 6, and 12 were previously illustrated in Sparling (1981a and/or 1983). Figures 7-9 are lateral views; all others are upper. All are ×40. 1, *Polygnathus linguiformis linguiformis* Hinde, S77VBb; 2, *P. l. linguiformis* n. morphotype of Sparling, S77VBa; 3, *Icriodus angustus* Stewart & Sweet, S77P28f; 4, *P.* sp. B of Sparling, left side fractured and displaced, S77P28c; 5, *P. augustipennatus* Bischoff & Ziegler, S77V7a; 6, *P. augusticostatus* Wittekindt (gerontic), S77P36b; 7, *P. intermedius* (Bultynck), S77V7b, 8, 9, *Prioniodina tortoides* Sparling, Pa, S77P33d, and Pb holotype, S77P37b; 10, *Polygnathus l. linguiformis* Hinde, distinctive morphotype, S80P7a; 11, *P. pseudofoliatus* Wittekindt, S80P12a; 12, *P. l. linguiformis* Hinde, S80P12d; 13, 14, *I. stephensoni* Sparling, S80P12b, S80P15c; 15, *I. orri* Klapper & Barrick, S80P18a.

regional correlation, based on geophysical logs, in which Eifelian volcanic ash beds play an important role (Rickard 1984, 1985, Sparling 1985). Ash beds have strongly influenced correlations over an even broader area since the 1960s.

Initially, a presumably single bed, the "Tioga bentonite," was traced from the subsurface of Pennsylvania to the base of the Seneca in the New York outcrop belt, to Ontario, to the Columbus/Delaware contact near Sandusky, and to the Illinois Basin (Oliver et al. 1968, Collinson 1968, Sanford 1968). Baltrusaitis (1974) suggested that a Michigan Basin ash bed, the Kawkawlin bentonite, was probably equivalent to the Tioga. He alluded to a higher one and questioned the identity of the alleged Tioga in Indiana (Droste and Vitaliano 1973) on grounds of stratigraphic position and lack of biotite, which is present in the Kawkawlin (Baltrusaitis 1975). Collins (1979) traced a biotitic bentonite identified as the Tioga in well cuttings from eastern Ohio and questioned the correlation with the non-biotitic ash bed near Sandusky, which was then disproven by conodonts as discussed above.

The original simple sheme, involving a single bentonite conveniently located at the top of the Onesquethaw Stage, thus broke down. The situation became even more complicated with the realization that the original Tioga from the starved-basin setting of the subsurface represents several distinct ash falls that accumulated over a very long period. Rickard (1984, pp. 822-824) discussed this situation and identified three beds (Tioga A, B, C) in the thicker Onondaga of the shelf region of western New York. They lie near the top of the Seneca (A), at its base (B), and in the underlying Moorehouse Member (C), which also includes a still lower ash bed designated "D" by Rickard (1984). The Tioga of the 1960s (i.e., at the base of the Seneca) now has been given the name Onondaga Indian Nation Metabentonite (Conkin and Conkin 1984).

Valid bentonite correlations can make remarkable contributions to stratigraphic syntheses. The tracing of a single bed through distinct lithofacies in Indiana that cannot otherwise be precisely correlated (e.g., Droste and Shaver 1975) is a good example. One setting where such correlation can be especially useful is in the subsurface of sedimentary basins, where biostratigraphic data are hard to obtain. Even if cores or samples are unavailable, ash beds can sometimes be traced on geophysical logs of bore holes, especially on gamma-ray logs.

In principle, γ-ray log correlation of bentonites in carbonate rocks should be a simple matter. Ash falling into a suitably quiet setting will end up as a relatively radioactive spike. Figure 16 provides examples taken from the literature. Well 1 is from Baltrusaitis' (1974) paper and lies close to the type well of the Kawkawlin bentonite. Wells 2-5 are from Gardner (1974), who traced that key bed over most of the Michigan Basin, relying extensively on γ-ray logs. Well 6 is from Rickard's (1984) paper on γ-ray-based correlations in the Lake Erie region.

If correlation by γ-ray logs is simple in principle, in practice it can leave much to be desired. Anyone can do it, but it inevitably reflects subjective judgments. For example, the dashed-line tracing of the Kawkawlin bentonite in Figure 16 was done by the author and corre-

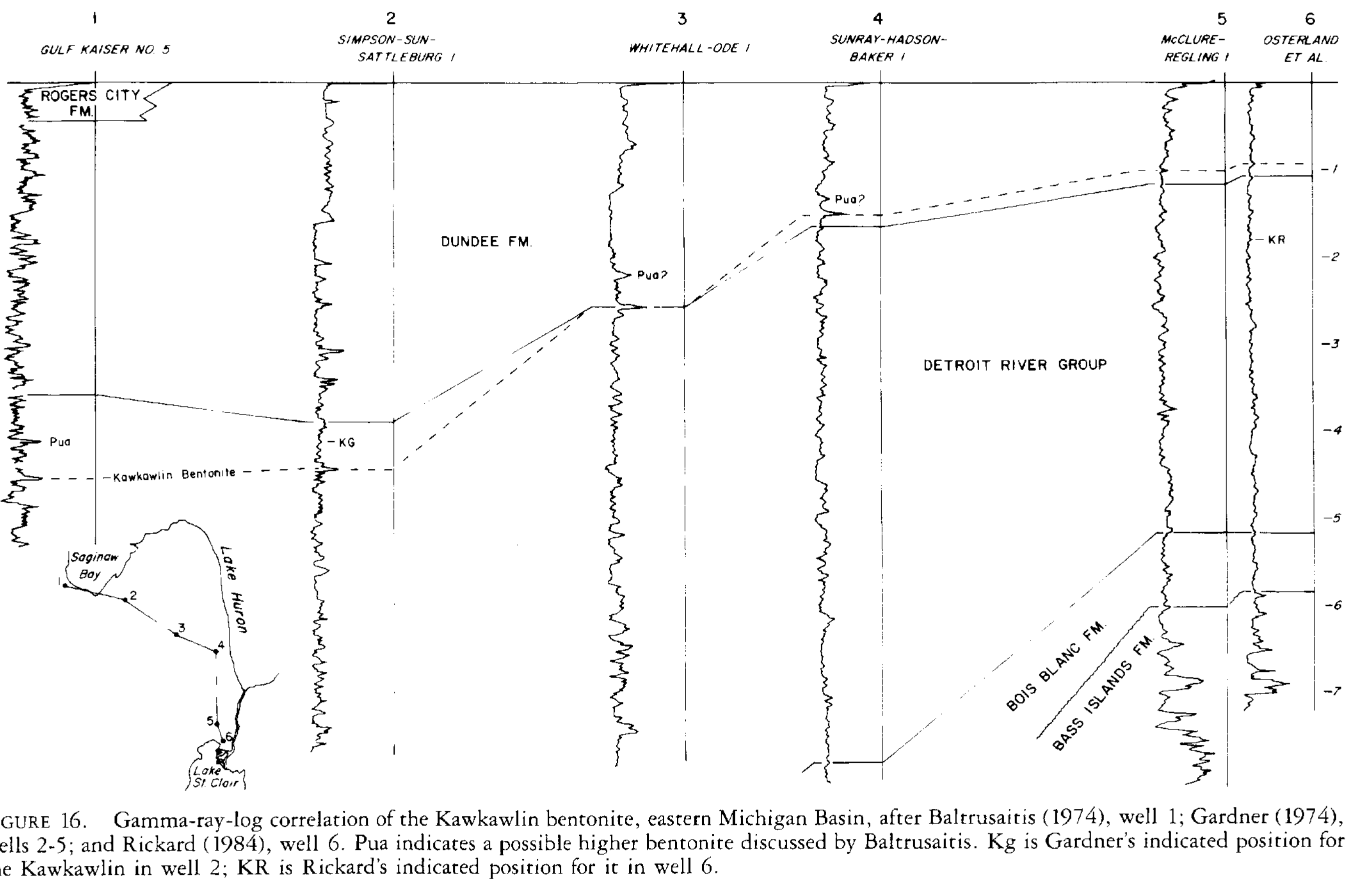

FIGURE 16. Gamma-ray-log correlation of the Kawkawlin bentonite, eastern Michigan Basin, after Baltrusaitis (1974), well 1; Gardner (1974), wells 2-5; and Rickard (1984), well 6. Pua indicates a possible higher bentonite discussed by Baltrusaitis. Kg is Gardner's indicated position for the Kawkawlin in well 2; KR is Rickard's indicated position for it in well 6.

sponds to that of Gardner in wells 3-5. It is consistent with our shared view that the top of the Detroit River is diachronous, although the author's subjective judgment disagrees with his picks for the top thereof in wells 4 and 5. In the interpretation of Baltrusaitis (1974, 1975), the Kawkawlin is confined to the Detroit River and absent from the region of wells 5 and 6 since he considered the upper Detroit River and the bentonite to be truncated by a major unconformity. Finally, Rickard's pick for the Kawkawlin (point KR) is consistent with his view that the top of the Lucas (=top of Detroit River) is synchronous (Rickard 1984, 1985).

Koch (1980, Fig. 7) considered the Lucas top to be diachronous and correlated the Kawkawlin bentonite with the Tioga (i.e., the one at the base of the Seneca). In response to my citing of his interpretation (Sparling 1985), Rickard (1985, p. 1220) stated that I had provided "no evidence, physical or biological, proving that the Tioga B ash bed and the Kawkawlin ash bed of Michigan are the same," whereas his interpretation (equating the Kawkawlin with bentonite D of New York) "at least has the physical support of the gamma-ray logs." Actually, the author had not claimed to prove any such thing but can now cite Figure 16 as physical evidence that the Kawkawlin and Tioga B ash beds could be equivalent. That position, however, involves a judgment and again illustrates the subjective nature of this approach.

Perhaps the most serious problem with correlation by geophysical logs is the fact that the stratigrapher tends to view patterns on paper as stratigraphic units rather than manifestations of single physical characteristics thereof. For example, Rickard (1984, Fig. 3) carried the Columbus of subsurface usage to the Parkertown quarry where he incorporates into it the lithologically distinct Lucas, apparently because it lies at the right position relative to a γ-ray log from a well 23 miles away. Even stranger is his treatment of the Delaware at this quarry. It was pointed out (Sparling 1985) that his Tioga B could not correspond to the one near the base of the Delaware near Sandusky since the former lies in the *costatus* Zone and the latter probably in the *kockelianus* Zone and certainly above the lower *australis* Zone. His response (Rickard 1985, p. 1218) was to reaffirm the validity of his γ-ray log correlation (all the way from New York), equate the basal Delaware ash bed with Tioga A instead of B, and correlate the base of the Delaware at Parkertown with the position of Tioga A on said γ-ray log from 23 miles away. No lithologic basis was presented for this change, which requires a decrease in Delaware thickness from about 14.5 m to about 3.5 m over the distance involved. Furthermore, Tioga A lies within the Seneca of New York and therefore within the *costatus* Zone (Klapper and Ziegler 1979, Text-Fig.4), although Rickard (1985, p. 1219) deals with that problem by decreeing that the base of the *australis* Zone "should be dropped to a point between ash beds A and B."

The main point of this section is the fact that bentonite correlations in general, and those based on geophysical-log tracing in particular, should be viewed with skepticism. This is certainly true when such correlations require the arbitrary shifting of conodont-zone boundaries. Another point to be made involves the fact that bentonite correlations tend to be accepted readily and adopted whether they are valid or not. Consistency with conodont zonation based on conodont sequences found in many parts of the world is clearly a useful test to which Middle Devonian bentonite correlations can be subjected.

GIVETIAN BIOSTRATIGRAPHY

Stauffer (1938) described conodonts from the upper Plum Brook Shale, but the lower part appears to have been covered virtually everywhere until the top of the Delaware and disconformably overlying basal Plum Brook were exposed at the Parkertown quarry in the early 1980s. The present study began with extraction of a wealth of conodont material from this basal section. Collection was then made from thin, argillaceous calcilutites in the upper Plum Brook and from the overlying Prout Dolomite at Bloomingville, in exposures that had been studied and described by Stumm (1942). Numerous well preserved conodonts were found in the upper Plum Brook, but the Prout disappointingly yielded only a small number of nondiagnostic specimens. However, publication of this fact (Hackathorn 1984, p. 30) led to good news from F. Huntley (pers. comm.). He had been doing field and laboratory studies of the Prout, and his etching of polished slabs (fortunately with acetic acid) was in some cases releasing fairly numerous conodonts. A single sample collected at his direction in 1985, less than 1 km from the Bloomingville section, yielded abundant and diagnostic conodonts.

The following sections will report on preliminary findings from this Givetian material. An additional objective will be to point out implications regarding regional correlation, especially in regard to current conodont-based correlations.

HISTORICAL BACKGROUND. Study of the upper Plum Brook and Prout began with Newberry (1873, 1874), who recognized these strata at Prout Station (~1.5 mi east-southeast of Bloomingville) and at a railroad cut to the north as being of Hamilton age. The "Prout Limestone" was first referred to as such by Prosser (1903); the Plum Brook Shale did not obtain its proper name until 1941 (Cooper 1941).

The shale above the Delaware in central Ohio was named the Olentangy by Winchell (1874), who considered it not to be equivalent to the more fossiliferous strata at Prout Station. However, Orton (1893) was the first of several to correlate the Plum Brook with the Olentangy. Stauffer (1909) adopted that view and made the first detailed studies of the Plum Brook and Prout in the area south and southeast of Sandusky. Grabau (1917) proposed the "Prout series," to include the Prout and the "Plum Creek" shale, and disputed correlation with the Olentangy, which he considered to represent continuous sedimentation during Late Devonian time.

Stauffer (1938) extracted conodonts from the Olentangy, the upper Plum Brook, and the Arkona Shale of Ontario, referring to all three units as Olentangy. His material from central to south-central Ohio was mostly from the upper Olentangy and consists of Upper Devonian taxa. Yet the faunas to the north were said to be "markedly similar."

The foregoing references form only a partial list of works dealing with the Olentangy and Plum Brook through the 1930s. The relationship between central and northern Ohio was a common theme, and correlations of the Plum Brook and Prout with other areas had been established. Cooper et al. (1942) summarized developments to that time. The Plum Brook was correlated with the upper Silica Shale of northwestern Ohio, the Arkona Shale of Ontario, and the Levanna Black Shale of New York. The Prout was correlated with the Tenmile Creek Dolomite of northwestern Ohio, the Hungry Hollow Formation of Ontario, and the Centerfield of New York. A major breakthrough also occurred (Cooper et al. 1942, p. 1774, Chart 4) in that the Olentangy was considered to include a lower part of Tully (middle Givetian) age, on the basis of the coral *Lopholasma* at its base, overlain by an Upper Devonian unit.

Stumm (1942) made a detailed study of the faunas of the upper Plum Brook and Prout. Among classes studied by him, 72 species were restricted to the Plum Brook, 87 to the Prout, with only eight species being common to both. He made no suggestion of a possible disconformable relationship, however, and essentially endorsed the correlations of Cooper et al. (1942) for northwestern Ohio, Ontario, and New York.

Meanwhile, the problem of the Olentangy Shale continued. Baker (1942) cited clear evidence for its Upper Devonian age, based on macrofossils, as did Stewart and Hendrix (1945b) on the basis of ostracodes. The Plum Brook ostracode fauna was found to be of Hamilton age and similar to that of the Silica Shale (Stewart and Hendrix 1945a, 1945b).

Ramsey (1969) extracted conodonts from the lower Olentangy and indicated that correlation with the middle-Givetian Tully of New York was possible. Tillman (1970) defined the Lower Olentangy in central Ohio, traced the disconformity at its top, and extracted a relatively diverse ostracode fauna from it. Of 20 species found in the Lower Olentangy, 16 occur also in the Plum Brook. Tillman indicated that they "appear to be correlative." Gable (1973) considered Lower Olentangy conodonts to support correlation with the Tully; Ziegler et al. (1976, p. 117) suggested an age no older than the Middle *varcus* Subzone.

In the most recent studies, Schwietering (1979) traced the Lower Olentangy into the Plum Brook with subsurface well cuttings and γ-ray logs and showed a steady northward thickening. Rickard (1984, Fig. 4) showed the same relationship.

It seems clear that a considerable amount of published work to date supports correlation of the Lower Olentangy with the Plum Brook. If so, the former cannot be the same age as the Tully, with which it was correlated by Cooper et al. (1942) and more recently by Johnson et al. (1985, Fig. 8) and Sparling (1985, Fig. 1). Further discussion of this problem follows.

PLUM BROOK CONODONT BIOSTRATIGRAPHY. The Plum Brook Shale is shown by Rickard (1984, Fig. 3) to be about 23 m thick in eastern Erie County. In the outcrop area it has not been measured, but Stauffer's (1938) collections extended to about 4.9 m below the top at Bloomingville. His figured material from the upper Plum Brook includes *Icriodus expansus, I. brevis* (his *I. cymbiformis?*), *I. obliquimarginatus* (his *I. latericrescens,* Pl. 52, Fig. 32—see Ziegler et al. 1976, p. 118), *Polygnathus l. linguiformis* (his *P. sanduskiensis*), and *P. strongi.* Among other taxa listed by Stauffer for this interval, *I. arkonensis* is likely to be present, but inclusion of the Upper Devonian species, *P. decorosus* and *P. webbi,* was probably based on specimens of *P. pseudofoliatus* or closely related species.

The basal Plum Brook at Parkertown consists of 1.2 m of arenaceous limestone (56% of total) and shale. Conodonts are abundant, silt-encrusted, sorted to some extent, but generally well preserved and diverse. Included are *I. expansus, I. arkonensis, I. brevis(?), I. latericrescens latericrescens, I. regularicrescens, P. l. linguiformis, P. pseudofoliatus, P. xylus ensensis, P. xylus xylus* (early form), and *P. eiflius.* Over 17 kg of material from two thin limestones in the upper Plum Brook, corresponding to zones D and F of Stumm (1942), have yielded *P. pseudofoliatus, P. xylus, P. l. linguiformis, P. intermedius, P. strongi, I. expansus, I. arkonensis* (uncommon), *I. brevis,* and *I. obliquimarginatus.* Figure 17 shows representative species from the basal unit (1-11) and from the upper limestones (12-15).

The Plum Brook fauna clearly belongs to the *ensensis* Zone; restriction to the upper (earliest Givetian) part is indicated by the fact that specimens of *P. xylus ensensis* are mostly "phyletically late forms" as described by Ziegler and Klapper (Ziegler et al. 1976, p. 126). Also, an early form of *P. xylus xylus* is present. The lowest reported occurrences of this subspecies elsewhere are in the overlying Lower *varcus* Subzone.

In a core from the Chatham Sag area of southwestern Ontario being studied currently by T. T. Uyeno, this *ensensis*-Zone fauna also occurs in the Bell Shale, Rockport Quarry Limestone, and Arkona Shale. This zone has not been clearly established elsewhere in eastern North America, although the Silica Shale and equivalent units in the Michigan Basin most likely fall within its limits.

Johnson et al. (1985) have cited evidence for a transgressive-regressive cycle (their T-R cycle If) that began during very late Eifelian time. The Bell Shale appears to represent the oldest record of the corresponding cyclothem in the Findlay-Algonquin arches region. The tops of the Arkona, Plum Brook, and Silica shales represent the youngest levels that can be assigned to it. This unit probably also includes the lower Traverse of northern Indiana (i.e., below the lowest occurrences of *P. "varcus"* of Orr 1971). Conodonts from this interval in northeastern Indiana (Doheny et al. 1975, pp. 40-42) were loaned by R. Shaver; all included species of *Icriodus* occur in the Plum Brook. The Silver Creek and Speed members of the North Vernon Limestone of central to southern Indiana have been given a latest Eifelian to earliest Givetian assignment (Orr 1971, Shaver et al. 1986), in part on the basis of reported occurrence of *I. l. latericrescens* in the highest part. This was questioned, however, by Klug (1983).

Where present, this cyclothem appears to be bounded by disconformities over much of the cratonic interior. The lower one is marked by a distinct faunal break as defined by species of *Icriodus. Icriodus orri, I. stephensoni* and *I. angustus* range to the very top of the Delaware Limestone in north-central Ohio. All three are missing from the basal Plum Brook, which includes *I. arkonensis, I. expansus,* and *I. l. latericrescens.* The demise of the Delaware species was likely caused by an extensive regression beginning in late *kockelianus*-Zone time. The ascent of *I. expansus* and *I. arkonensis* probably accompanied a slow

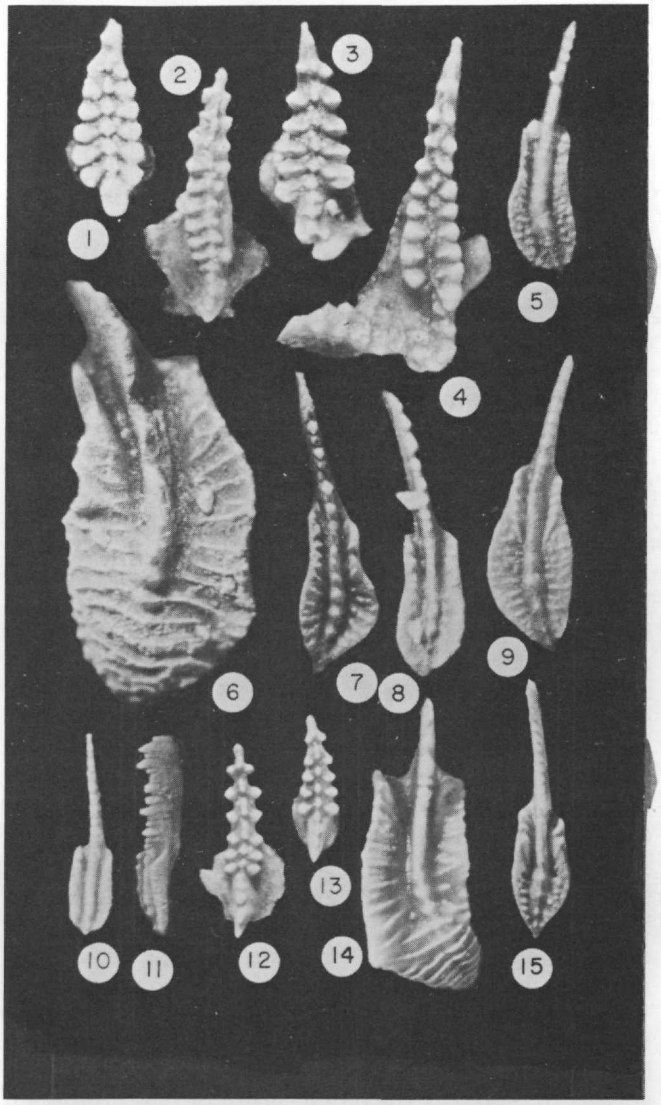

FIGURE 17. Conodonts from the basal Plum Brook at the Parkertown quarry (1-11) and limestones in the upper Plum Brook at Bloomingville (12-15). All are upper views except 11 (oblique), and all are ×40. 1, *Icriodus expansus* Branson & Mehl, S81P9b; 2, *I. regularicrescens* Bultynck. S82P6a; 3, *I. arkonensis* Stauffer (aberrant), S81Pa; 4, *I. latericrescens latericrescens* Branson & Mehl, S81P10b; 5, *Polygnathus pseudofoliatus* Wittekindt, S82P6e; 6, *P. linguiformis linguiformis* Hinde (gerontic), S81P10d; 7, *P.* aff. *P. eiflius* Bischoff & Ziegler of Klapper, S82P9c; 8, *P. xylus ensensis* Ziegler & Klapper, S81P11c; 9, *P. eiflius* Bischoff & Ziegler, S82P6d; 10, 11, *P. xylus xylus* Stauffer (early form), S82P9d; 12, *I. obliquimarginatus* Bischoff & Ziegler, S84B1f (from zone D of Stumm 1942); 13, *I. brevis* Stauffer, S84B1c; 14, *P. 1. linguiformis* Hinde, S84Ble; 15, *P. strongi* Stauffer, S82B2a (from zone F of Stumm 1942).

marine transgression onto the carbonate shelf of Figure 3 in latest Eifelian to earliest Givetian time. The origin of *I. l. latericrescens* could have occurred earlier, since highest known occurrences of its predecessor, *I. latericrescens robustus,* are in the *australis* Zone. Two other early Givetian arrivals, *I. brevis* and *I. obliquimarginatus,* may be absent from strata just above the disconformity owing to paleoecologic controls on their distribution.

Regarding the problem of correlation with the Lower Olentangy Shale, assignment of that unit to the Middle *varcus* Subzone by Ziegler et al. (1976, p. 117) was based on the assumption that *I. brevis, I. expansus,* and *P. linguiformis klapperi* "do not occur lower in North American sections . . ." The first two do occur in the Plum Brook, but the third is not found among the thousands of specimens collected therefrom. Its presence in the relatively unfossiliferous Lower Olentangy is therefore reasonable evidence against correlation of the two shales.

The disconformity at the top of the If cyclothem in Ontario has been described by Landing and Brett (1987). It lies within the uppermost Arkona as defined in some previous classifications (e.g., Uyeno et al. 1982). A single specimen of *P. timorensis* from the base of the overlying Hungry Hollow, as defined by Landing and Brett (1987, p. 211), served as the basis for assignment to the Lower *varcus* Subzone for which that species is diagnostic. That species also occurs in the upper Traverse of northeastern Indiana (*P. varcus* of Orr 1971, Pl. 5, Figs. 4-8), and in the Beechwood Member of the North Vernon Limestone of central to southern Indiana (Klug 1983). It is also present in the Prout, which cannot, however, be given that zonal assignment.

PROUT CONODONT BIOSTRATIGRAPHY. As indicated above, a single sample from the Prout has yielded many diagnostic conodonts (Fig. 18). It was taken from near the base of the Prout about 1.4 km (northeast of Bloomingville and contained specimens of *I. arkonensis, I. expansus, I. brevis, I. l. latericrescens, I. obliquimarginatus, I. difficilis, P. l. linguiformis, P. linguiformis klapperi, P. pseudofoliatus, P. xylus ensensis, P. x. xylus, P. timorensis, P. rhenanus, P. ovatinodosus,* and *P. ansatus.* The last three are diagnostic for the Middle *varcus* Subzone.

This age assignment is perfectly logical in that the Prout can be attributed to the T-R cycle that followed If. This is cycle IIa of Johnson et al. (1985) and corresponds to the Taghanic onlap of Johnson (1970). On the other hand, this conodont zonation is at odds with nearly all current correlation charts for the arches and platform region, which show an anomalous hiatus for the time in question. It also conflicts with long-standing correlations with the Beechwood of Indiana, Tenmile Creek Dolomite of northwest Ohio, Hungry Hollow of Ontario, and Centerfield Limestone of New York.

It seems likely that this conflict involves one of the problems that always exists in biostratigraphy, the matter of guide fossils that are missing for one reason or another. The species in question here is *P. ansatus,* the lowest occurrence of which is used to define the Middle *varcus* Subzone (Ziegler et al. 1976, p. 113). Existence of *P. timorensis* without *P. ansatus* is thus understandably a logical basis for assignment of strata to the Lower *varcus* Subzone, the base of which is defined by lowest occurrences of the former. However, that situation is not uncommon in strata belonging to the Middle *varcus* Subzone. Among samples from strata clearly assigned to it tabulated by Ziegler et al. (1976), nearly half contain *P. timorensis* without *P. ansatus,* and only about one-fourth include both.

Although *P. ansatus* is not reported from the Beechwood, *P. linguiformis klapperi* and *P. linguiformis weddigei* have been (Klug 1983). The latter is known elsewhere *only* from the Middle *varcus* Subzone. In Ontario, *P.*

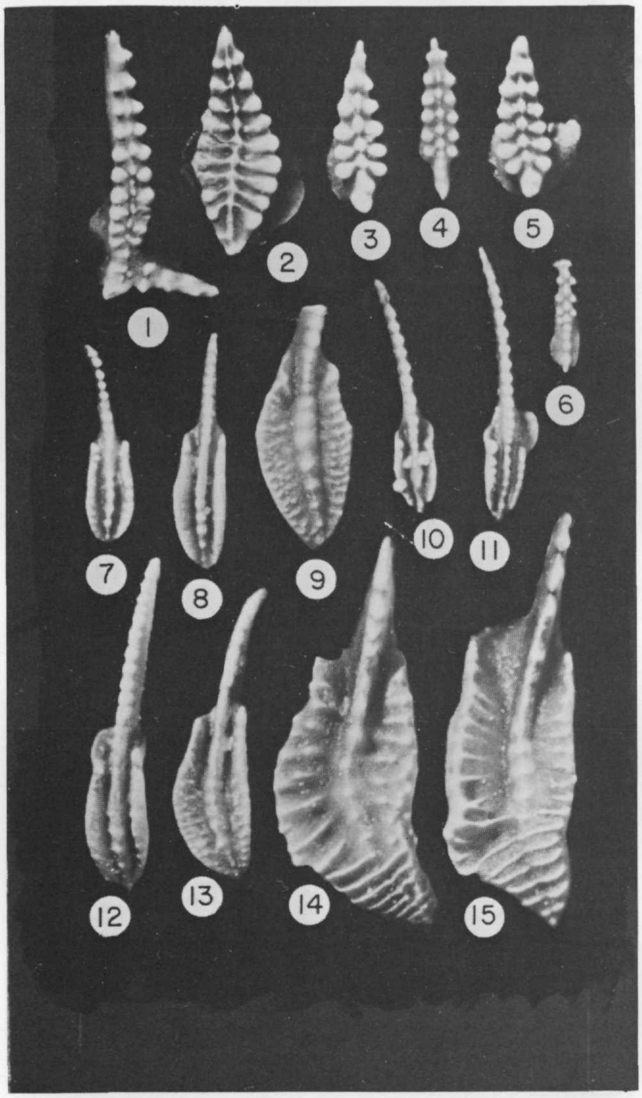

FIGURE 18. Conodonts from near the base of the Prout at the Campbell Road site of Huntley, east branch of Pipe Creek. All are upper views, ×40. 1, *Icriodus latericrescens latricrescens* Branson & Mehl, S85CR91; 2, *I. arkonensis* Stauffer, S85CR9k; 3, *I. expansus* Branson & Mehl, S85CR9p; 4, *I. brevis* Stauffer, S85CR9x; 5, *I. difficilis* Ziegler & Klapper, S85CR9o; 6, *I. obliquimarginatus* Bischoff & Ziegler (anterior end broken), S85CR9w; 7, *Polygnathus xylus ensensis* Ziegler & Klapper, S85CR9h; 8, *P. xylus xylus* Stauffer, S85CR9a; 9, *P. ovatinodosus* Ziegler & Klapper, S85CR9z; 10, *P. timorensis* S85CR9g; 11, *P. rhenanus* Klapper, Philip & Jackson, S85CR9q; 12, *P. ansatus* Ziegler & Klapper, S85CR9d; 13, *P. pseudofoliatus* Wittekindt, S85CR9e; 14, *P. linguiformis klapperi* Clausen, Leuteritz & Ziegler, S85CR9aa; 15, *P. linguiformis linguiformis* Hinde, S85CR9ff.

timorensis occurs rather abundantly without *P. ansatus* in the upper Widder and Ipperwash (Uyeno et al. 1982, Table 6); also absent, however, are any other species in the *P. varcus* Group, so extremely limiting paleoecologic conditions are indicated.

In regard to the Centerfield of New York, assignment to the Lower *varcus* Subzone (Ziegler et al. 1976, p. 113) is based on very limited material (G. Klapper pers. comm.). Also, Brett and Baird (1985) showed the Centerfield to be a regressive unit within shales reflecting deeper-water conditions. It is thus not likely to be equivalent to clearly transgressive carbonates above a widespread disconformity such as the Prout and Hungry Hollow. Thus, even if the Centerfield is correctly assigned to the Lower *varcus* Subzone, the Prout and equivalents could be considerably younger.

On the basis of these arguments, the following hypothesis is proposed: that the Prout, Hungry Hollow and overlying Middle Devonian strata, Tenmile Creek Dolomite, and the upper Traverse and Beechwood of Indiana all belong to the Middle *varcus* Subzone and are approximate equivalents of the lower Tully Limestone of New York. Included in this cyclothem would be the Little Rock Creek Limestone of Indiana (Cooper et al. 1942). In addition, since the Taghanic onlap was more extensive than earlier Givetian transgressions (Johnson 1970), it is reasonable to assume that the only Givetian strata of central Ohio, the Lower Olentangy Shale, should be correlated with the Prout.

LAKE ERIE REGIONAL CORRELATION

Figure 19 summarizes correlation in the Lake Erie region based mainly on conodont data and the interpretations presented above. It represents a considerable modification of an earlier version (Sparling 1985) resulting from new information and some second thoughts.

Perhaps the greatest remaining problems involve the New York section, especially those segments for which conodont zonation has not been established. Some of the most recent work in the Middle Devonian of this area is that of Baird and Brett (1986). They cite evidence for a disconformity at the top of the Seneca that could correspond to the erosional interval that followed Columbus sedimentation. They also describe another disconformity in the form of a "corrasional hardground" beneath the Oatka Creek Shale. The post-Cherry Valley hiatus could conceivably be quite large, even to the extent that the Oatka Creek could belong to the If cyclothem discussed above. If so, Rickard's (1984) correlation of the Oatka Creek with the Plum Brook and Arkona could be valid. The dotted lines on Figure 19, however, show correlations (Rickard 1984, 1985) that are clearly at odds with conodont biostratigraphy. His most recent equation of Tioga A with the basal Delaware bentonite was discussed above. The Cherry Valley cannot be equivalent to the Rockport Quarry Limestone since the former is in the *kockelianus* Zone, whereas the latter lies above the lowest occurrences of *Polygnathus xylus ensensis,* which is diagnostic for the *ensensis* Zone.

From the standpoint of intracratonic Middle Devonian stratigraphy, it is certainly fortunate that intercontinental conodont zonation has eliminated much of the uncertainty that characterized earlier biostratigraphic studies tied to the New York Standard. Problems (e.g., the possibility of missing guide species) exist, but the overall contribution that conodonts have made is truly remarkable.

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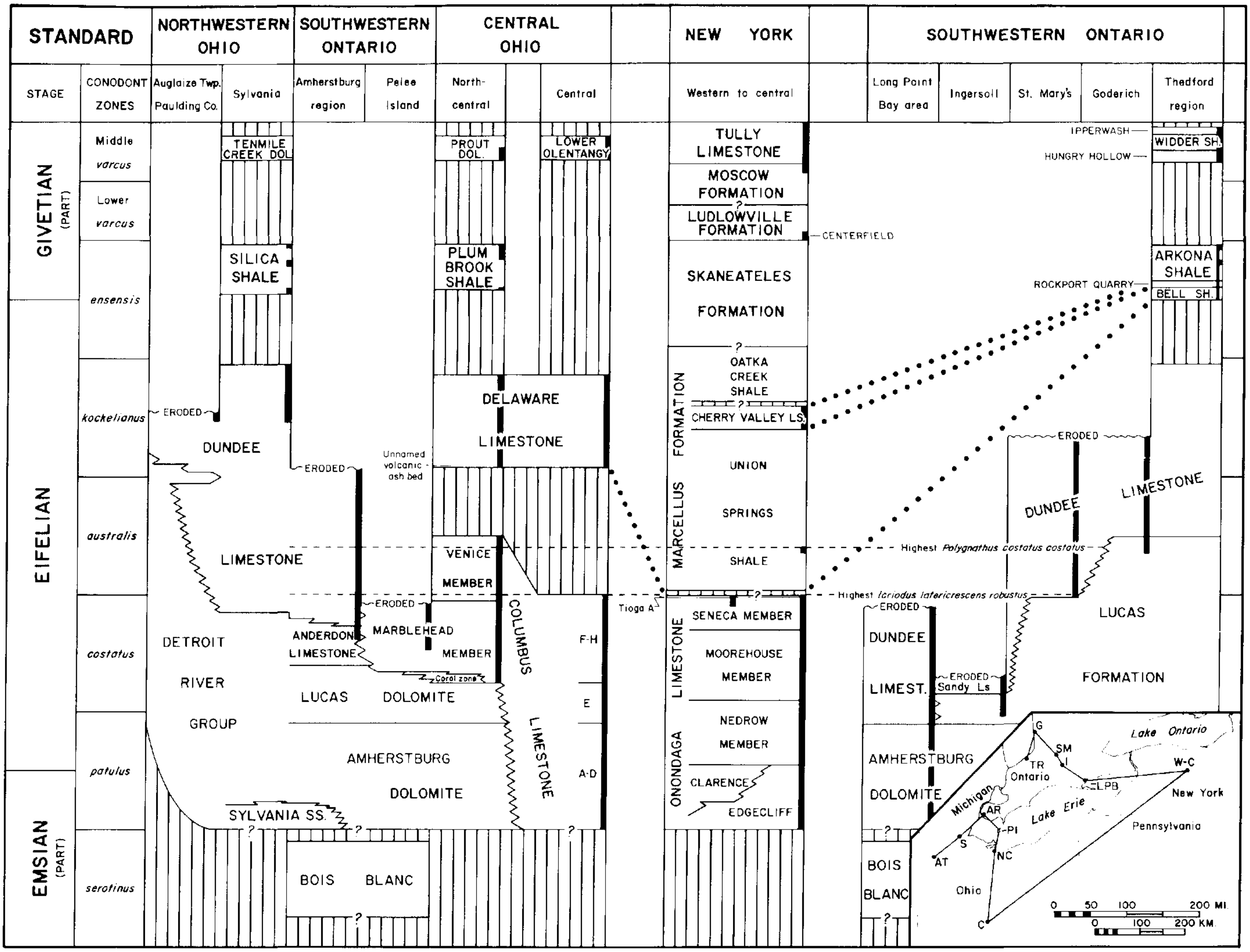

FIGURE 19. Conodont-based correlation of Middle Devonian strata in the Lake Erie region. Wide vertical lines indicate intervals from which conodonts have been studied (study by T. T. Uyeno of some material near the Thedford region is preliminary). Dotted lines indicate some of the correlations of Rickard (1984, 1985) that are inconsistent with conodont data. Sources are Auglaize Township, Shaver et al. (1971); Sylvania, Klapper and Ziegler (1967) and Klapper and Johnson (1980); Southwest Ontario, Stauffer (1938), Orr (1971), Uyeno et al. (1982), and Landing and Brett (1987); North-central Ohio, Stauffer (1938) and Sparling (1983 and herein); central Ohio, Ramsey (1969) and Ziegler et al. (1976); New York, Klapper (1971, 1981) and Ziegler et al. (1976).

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